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**(54) METHOD FOR ADJUSTING EXPOSURE ENERGY OF LED PRINT HEAD AND LED PRINT HEAD  
WITH ADJUSTED EXPOSURE ENERGY**

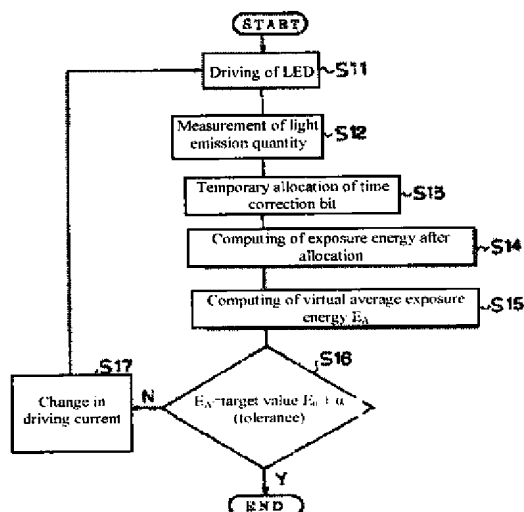
**(57) Abstract**

**Purpose**

To perform adjustment of the driving current for each chip of the LED print head and adjustment of the time correction bit for each LED at a high efficiency.

**Constitution**

When adjustment of the driving current of chip is performed, allocation of the time correction bit is being considered. Consequently, when LED is driven and the light emission quantity is measured, the time correction bit is temporarily allocated, and, in this case, the virtual average exposure energy is computed and compared with the target value.



## CLAIMS

1. A method for adjusting the exposure energy of LED print head characterized by the following facts: in order to have the exposure energy for the LED print head as a row of multiple chips, each having multiple LEDs set as a row uniform at the target value, correction of the light emission quantity among various chips is performed by adjusting the LED driving current, and correction of the light emission timing of the LEDs in each chip is performed by adjusting the feeding timing of the driving current; in this method for adjusting the exposure energy of the LED print head, there are the following steps of operation:

- a step of driving LEDs by a prescribed driving current,
- a step of measuring the light emission quantity of each LED,
- a step of allocating the time correction bit for each LED,
- a step of computing the exposure energy for each LED on the basis of said driving current and temporarily allocated time correction bit,
- a step of computing the virtual average exposure energy from the exposure energy of each LED,
- a step of comparing said virtual average exposure energy with the target value,
- and a step of changing the driving current on the basis of said comparison result; and
- each step mentioned above is repeated until the virtual average exposure energy reaches a desired target value.

2. A type of LED print head adjusted using the exposure energy adjusting method described in Claim 1.

## DETAILED EXPLANATION OF THE INVENTION

[0001]

### **Industrial application field**

The present invention pertains to a method for adjusting the exposure energy for having the exposure energy of an LED print head carried on a printer or a fax machine uniform at the target value. Especially, the present invention pertains to a method for adjusting the exposure energy of the LED print head as a row of multiple chips, each having multiple LEDs set as a row characterized by the fact that correction of the light emission quantity among the chips is performed by adjusting the driving current of each LED, and adjustment of the exposure energy of the LEDs in each chip is performed by adjusting the feeding timing of the driving current.

Also, the present invention pertains to a type of LED print head with its exposure energy adjusted by means of said adjustment method.

[0002]

**Prior art**

For an LED print head, printing is performed by selectively feeding driving current to the LEDs corresponding to the printing dots for the LEDs set as a row along the printing line so that the LEDs emit light to perform line printing for each row. For this type of print head, it is necessary to perform adjustment to have a uniform exposure energy of the LEDs set as a row to ensure uniform printing quality for each line.

[0003]

It is well known that the exposure energy of LED depends on the magnitude and feeding timing of the driving current. Usually, in order to suppress dispersion in the light emitting efficiency among the LED elements, it is preferred that as many as possible LEDs be formed on the same chip. In order to realize the necessary printing width, it is necessary to assemble multiple chips as a row for printing. Consequently, for the LED print head having multiple chips set as a row, usually, adjustment of the light emission quantity among the chips is performed by adjusting the driving current fed to each chip. With regard to the dispersion in the light emitting efficiency of LEDs in each chip, the driving current feeding timing for each LED is adjusted by means of allocation of the time correction bit. That is, for the LED driving current, the feeding timing is controlled by controlling the principal driving current pulse set equal for the various LEDs and the time correction bit pulse connected to it, and the number and duration of the time correction bit pulses are adjusted corresponding to the dispersion in the quality of the LED elements.

[0004]

Figure 4 is a diagram illustrating the method for adjusting the exposure energy of the printing head in the prior art. As shown in Figure 4, according to the adjustment method of the prior art, first of all, for each chip, the driving current is adjusted so that the average light quantity becomes the target value. Then, for the overall printing head made of a combination of multiple chips, allocation is performed for the time correction bit to have uniform exposure energy for the entirety.

[0005]

That is, in the prior art, an arbitrary initial driving current is fed to the LED chip as the adjustment object (S1). In this case, the light emission quantity is measured for each LED (S2). At this time, the driving current fed to each LED is only the main pulse, and the pulse of the time correction bit is not considered.

[0006]

Then, from the light emission quantity of said LEDs, the average light quantity  $L_A$  is computed (S3). Then, said average light quantity  $L_A$  is compared with target value  $L_0$  (S4). In comparison performed in step S4, a prescribed tolerance  $\alpha$  is given to target value  $L_0$ . In step S4, if comparison indicates that average light quantity  $L_A$  is in agreement with the target value, adjustment of the driving current is finished. On the other hand, when the two are not in agreement with each other, the initially set driving current is changed (S5), and the operation of steps S1-S4 is performed repeatedly.

[0007]

After a few rounds of repeated operation, average light quantity  $L_A$  reaches target value  $L_0$  in step S4. As a result, adjustment of the driving current is finished. Then, for all of the chips assembled in the printing head, allocation is performed for the time correction bit for each LED (S6). The allocation operation is performed by feeding said adjusted driving current to the corresponding chip and measuring the light emission quantity of each LED. Usually, for the LED with the highest light emission quantity, only the main pulse without adding the time correction bit is applied to determine the exposure energy, and the time correction bit is given to the other LEDs to have the same exposure energy.

[0008]

As explained above, in the prior art, adjustment of the exposure energy of the printing head is performed by 2-step adjustment operation including determination of the driving current for each chip and allocation of the time correction bit for all of the LEDs.

[0009]

#### **Problems to be solved by the invention**

However, for the adjustment method of the prior art, when allocation of the time correction bit is performed, the final adjustment of the exposure energy of all of the LEDs contained in multiple chips should be performed. Consequently, the burden of the time

correction bit rises, and the correction bit number prepared beforehand must be large enough so as to correspond said significant adjustment.

[0010]

This has the following disadvantage: the light emitting time itself for the time correction bit in the practical printing operation becomes longer, and this leads to restriction on the printing time and printing quality of the printing head.

[0011]

Also, in the prior art, when the driving current is determined, the time correction bit is not considered at all. Consequently, even when target value  $L_0$  of the light quantity is constant, as dispersion of the LED elements becomes larger for each printing head, the final average exposure energy becomes larger for each printing head, which is undesired, because this leads to a decline in the quality of the printing head.

[0012]

The purpose of the present invention is to solve the aforementioned problems of the prior art by providing an improved method of adjusting the exposure energy characterized by the fact that while the exposure energy of the LEDs can be made highly uniform, it is possible for the average exposure energy among various printing heads to be made much more uniform. Also, the present invention provides a type of LED print head adjusted using the exposure energy adjustment method.

[0013]

#### **Means for solving the problems**

In order to realize the aforementioned purpose, the present invention provides a method for adjusting the exposure energy of LED print head characterized by the following facts: in order to have the exposure energy for the LED print head as a row of multiple chips each having multiple LEDs set as a row uniform at the target value, correction of the light emission quantity among the various chips is performed by adjusting the LED driving current, and correction of the light emission timing of the LEDs in each chip is performed by adjusting the feeding timing of the driving current; in this method for adjusting the exposure energy of the LED print head, there are the following steps of operation: a step of driving LEDs by a prescribed driving current, a step of measuring the light emission timing of each LED, a step of allocating the time correction bit for each LED, a step of computing the exposure energy for each LED on the basis of said driving current and temporarily allocated time correction bit, a step of computing the virtual

average exposure energy from the exposure energy of each LED, a step of comparing said virtual average exposure energy with the target value, and a step of changing the driving current on the basis of said comparison result.

[0014]

Also, the present invention provides a type of LED print head adjusted using the aforementioned adjustment method.

[0015]

#### **Operation**

According to the aforementioned method, when the driving current for each chip is adjusted, it is always assumed that the time correction bit is allocated, and the exposure energy is computed. As a result, it is possible to perform adjustment of both the driving current and the time correction bit at the same time.

[0016]

#### ***Application Examples***

In the following, an explanation will be given regarding preferable application examples of the present invention with reference to figures.

[0017]

Figure 1 is a flow chart illustrating an application example of the method for adjusting the exposure energy according to the present invention.

[0018]

For each LED of the chip as the object of adjustment of the driving current that is preset at will initially, various LEDs are driven at the same time (S11). Here, the light emission quantity of each LED is measured (S12).

[0019]

As a characteristic feature of the present invention, when adjustment of the driving current is performed, allocation of the time correction bit is performed at the same time. That is, on the basis of the light emission quantity of each LED measured as aforementioned, the time correction bit for each LED is virtually allocated (S13). Usually, the virtual allocation is performed on the basis of the light emission quantity of each LED. For example, for the LED with the highest light emission quantity, no allocation of the time correction bit is performed, and

allocation of the time correction bit is performed corresponding to the insufficiency in the light emission quantity for each LED with a lower light emission quantity. After the virtual allocation of the time correction bit in this way, the exposure energy of each LED is computed from the virtually allocated time correction bit and the applied driving current (S14). Then, on the basis of the exposure energy of each LED, virtual average exposure energy  $E_A$  is computed for the chip (S15).

[0020]

Then, said virtual average exposure energy  $E_A$  is compared with target value  $E_0$  (S16). Of course, in step S16, a prescribed tolerance  $\alpha$  is given to target value  $E_0$  of the average exposure energy.

[0021]

Usually, in the initial comparison performed as aforementioned, virtual average exposure energy  $E_A$  and target value  $E_0$  are not in agreement with each other, and, due to the comparison result, the driving current is changed (S17). Then, according to the newly set driving current, the various LEDs are driven. Said steps S11-S16 are performed repeatedly. In step S16, virtual average exposure energy  $E_A$  becomes in agreement with target value  $E_0$ , and the adjustment comes to an end.

[0022]

Consequently, according to the present invention, each time when the driving current is changed, allocation of the time correction bit under the new driving current is performed, and adjustment is performed while the exposure energy of the chip is determined for each adjustment cycle.

[0023]

Consequently, according to the present invention, it is possible to perform adjustment of the driving current and adjustment of the time correction bit at the same time.

[0024]

In addition, even when adjustment is performed for each chip in this way, because virtual average exposure energy  $E_A$  of the chip is always adjusted to be in agreement with target value  $E_0$ , by simply adjusting each chip individually, it is possible to ensure that the final average exposure energy is extremely uniform for all of the chips assembled in the printing head.

[0025]

When adjustment of the driving current is performed, usually, the time correction bit is taken into consideration. Consequently, it is possible to ensure reliable prevention of the following trend in the prior art: dispersion of the final average exposure energy for each chip, or settlement on a relatively large value.

[0026]

As can be seen from Figure 1, in each adjustment cycle, the time correction bit is newly allocated each such time. This is because the time correction bit for each LED varies when the driving current is changed. It is well known that LED has nonlinear light emitting characteristics with respect to driving current. Usually, as the driving current applied on a chip falls, the light emitting dispersion of the LEDs in the chip tends to become larger. Due to such characteristics, an effective method is to perform a new allocation of the time correction bit each time when the driving current is changed. As an application example, the time correction bit comprises 3 bits. In each adjustment cycle, allocation of the 3 bits is stored in a memory not shown in the figure. Also, in each cycle, it is uploaded and renewed. Consequently, in step S16, the time correction bit when said virtual average exposure energy  $E_A$  becomes in agreement with target value  $E_0$  can be adopted as the final adjustment value.

[0027]

Figure 2 is a diagram illustrating a different application example of the present invention. In this application example, setting of the driving current is performed by means of bit setting of DAC (digital analog converter).

[0028]

For the printing head, control of the driving current of each chip is performed by means of DAC. The adjustment value stored as digital data in a memory not shown in the figure is read from the DAC as an analog value, and, as will be explained later in detail, this analog control signal is sent as a control signal to the gate controlling element of MOS-FET that feeds driving current to each chip As to be explained later in detail. Such DAC, for example, has a capacity of 10 bits, and it can execute extremely fine driving current adjustment.

[0029]

Figure 2 is a diagram illustrating an application example of control of the driving current using said DAC.



[0030]

In step S21, the bit number  $n$  of the DAC is set. As an application example,  $n$  is set to be 10.

[0031]

In step S22, the initial driving current is set. In the application example, the  $n^{\text{th}}$  bit, that is, the 10<sup>th</sup> bit, of the DAC is set at “1”, while the remaining bits are all set at “0”. In the DAC shown in the application example, each bit becomes the driving state at “0”. Consequently, in step S22, the driving current is set such that only the most significant bit is in the OFF state, while all of the remaining bits are set in the ON state.

[0032]

Due to this driving current, the DAC output is fed to the chip, and a driving current is fed to each LED (S23). In this case, the light emission quantity is measured for each LED (S24). In this state, the temporary allocation of the time correction bit, a characteristic feature of the present invention, is performed (S25). In this application example, too, the time correction bit comprises 3 bits, and, corresponding to the light emission quantity of each LED, no time correction bit is given to the LED having the highest light emission quantity, while for the other LEDs, the time correction bit is virtually allocated corresponding to the insufficiency in the light emission quantity.

[0033]

Then, the exposure energy after said allocation is computed for each LED (S26). On the basis of the exposure energy for each LED, virtual average exposure energy  $E_A$  of the chip is computed (S27).

[0034]

Next, said virtual average exposure energy  $E_A$  is compared with target value  $E_0$  (S28).

[0035]

In this application example, in step S28, whether virtual average exposure energy  $E_A$  is larger than target value  $E_0$  is taken as a judgment standard. If it is smaller than the target value, the  $n^{\text{th}}$  bit that has been initially set is changed to “0” (S29). That is, the change is made in the direction of increase in the driving current. On the other hand, if the comparison result is the opposite, that is, if virtual average exposure energy  $E_A$  is larger than the target value, the  $n^{\text{th}}$  bit is kept as is, that is, at “1”. In this way, the most significant bit is fixed.

[0036]

In step S30, judgment is made on whether determination has been made for all of the bits. If n is not 0, initial value n is subtracted by 1 at a time in step S31.

[0037]

The operation from S22 to S29 is performed repeatedly from the most significant bit to the least significant bit sequentially, and various bit values of DAC are fixed.

[0038]

As can be seen from the application example, in determination of various bit values each time, the virtual allocation of the time correction bit is performed, and, while the exposure energy is computed from the driving current and the time correction bit, the prescribed adjustment is performed.

[0039]

Consequently, in the state with all of the bits of the DAC fixed, allocation of the time correction bit is completed at the same time.

[0040]

Figure 3 is a diagram illustrating the overall driver of the LED print head that controls the driving current by the DAC shown in Figure 2.

[0041]

The printing head comprises multiple chips (10-1), (10-2), (10-3),... set as a row. In each chip (10), multiple LEDs (12-1)-(12-64) are set as a row. For each chip (10), drivers (14-1), (14-2), (14-3) are set to determine the driving currents by means of DAC (16-1), (16-2), (16-3).

[0042]

The interiors of drivers (14) have the same circuit constitution, and only driver (14-1) is shown in detail in Figure 3.

[0043]

For each LED (12), MOS-FET (18) for driving it is set, and it feeds the driving current to selected LED (12). Switching element (20) is connected to the gate of FET (18), by means of the output signal from AND gate (22), desired FET (18) is controlled ON/OFF, and, as explained

above, it is possible to feed the driving current adjusted according to the present invention from FET (18) to each said LED (12).

[0044]

Strobe signal STR is fed to one input of said AND gate (22), and the print control signal from data controller (24) is sent to the other input of said AND gate.

[0045]

According to the present invention, as explained above, in order to adjust the dispersion in light emitting of each LED in the chip, control is performed on both application of the correction pulse by the time correction bit and application of the main pulse for printing, and said power amplifier (24) performs switching between the correction data and the main data. When the time correction bit is determined by the present invention as aforementioned, the correction data are sent to latch (26), and are stored there as a characteristic value for the corresponding chip (10).

[0046]

On the other hand, the printing data are sent to shift register (28), and the data are temporarily stored by latch (30) as a parallel signal.

[0047]

As explained above, the correction data and the main data are stored in said two latches (26), (30). In the practical operation, correlation data (26) are also temporarily stored in the latch for the LED needed for printing according to the printing signal DIN sent to shift register (28). Said data controller (24) controls so that the outputs of said two latches (26),(30) are switched in a prescribed order, while they are sent to AND gate (22), and, under control of strobe signal STR and AND, said switching element (20) is turned ON, and, in this case, a driving current determined by DAC (16) is sent to selected LED (12), and light emitting is performed with the desired exposure energy adjustment.

[0048]

As explained above, according to the present invention, it is possible to perform correction of the driving time of each LED and adjustment of the driving current for each chip in the optimum state for the practical printing operation.

[0049]

### **Effects of the invention**

As explained above, according to the present invention, it is possible to perform adjustment of the LED print head with the practical exposure energy determined from both the driving current and the driving time, so that it is possible to realize extremely uniform exposure energy, and it is possible to significantly improve the printing quality of the printing head.

[0050]

Also, according to the present invention, the target value of the final exposure energy is taken as the reference, so that dispersion in the printing quality for each chip can be reduced significantly, and, even when multiple chips are assembled to form the printing head, it is still possible realize a highly uniform exposure energy. In addition, it is possible to obtain a head with minimum dispersion in the exposure energy among various printing heads.

[0051]

In addition, it is possible to perform adjustment of the exposure energy in chip unit. Consequently, the burden on the time correction bit can be reduced, so that it is possible to reduce the number of bits in the time correction bit than the prior art.

## **BRIEF DESCRIPTION OF THE FIGURES**

Figure 1 is a flow chart illustrating a prescribed application example preferable for the adjustment method of the present invention.

Figure 2 is a flow chart illustrating another preferable application example for the adjustment method of the present invention. It shows a preferable application example for the method for adjusting the driving current using DAC.

Figure 3 is an overall diagram illustrating the printing head driving system in the present invention.

Figure 4 is a flow chart illustrating the adjustment method in the prior art.

### **Brief description of the keys**

S11, S23	Driving of LED
S12, S24	Measurement of light emission quantity
S13, S25	Virtual allocation of time correction bit
S14, S26	Computing of exposure energy after allocation

S15, S27      Computing of virtual average exposure energy  
 S16, S28      Comparison  
 S17, S29      Change in driving current

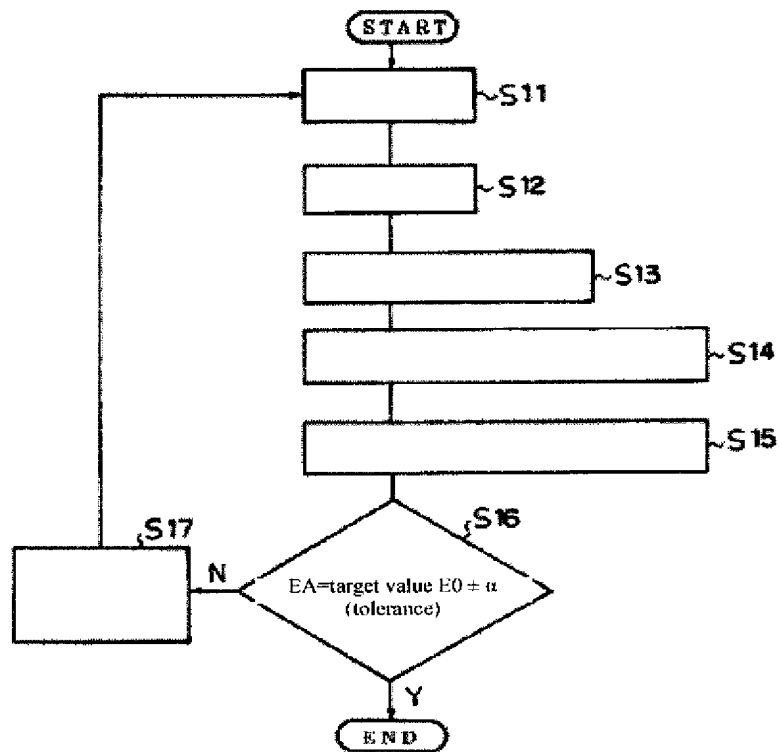


Figure 1.

S11      Driving of LED  
 S12      Measurement of light emission quantity  
 S13      Virtual allocation of time correction bit  
 S14      Computing of exposure energy after allocation  
 S15      Computing of virtual average exposure energy  
 S16      Comparison  
 S17      Change in driving current

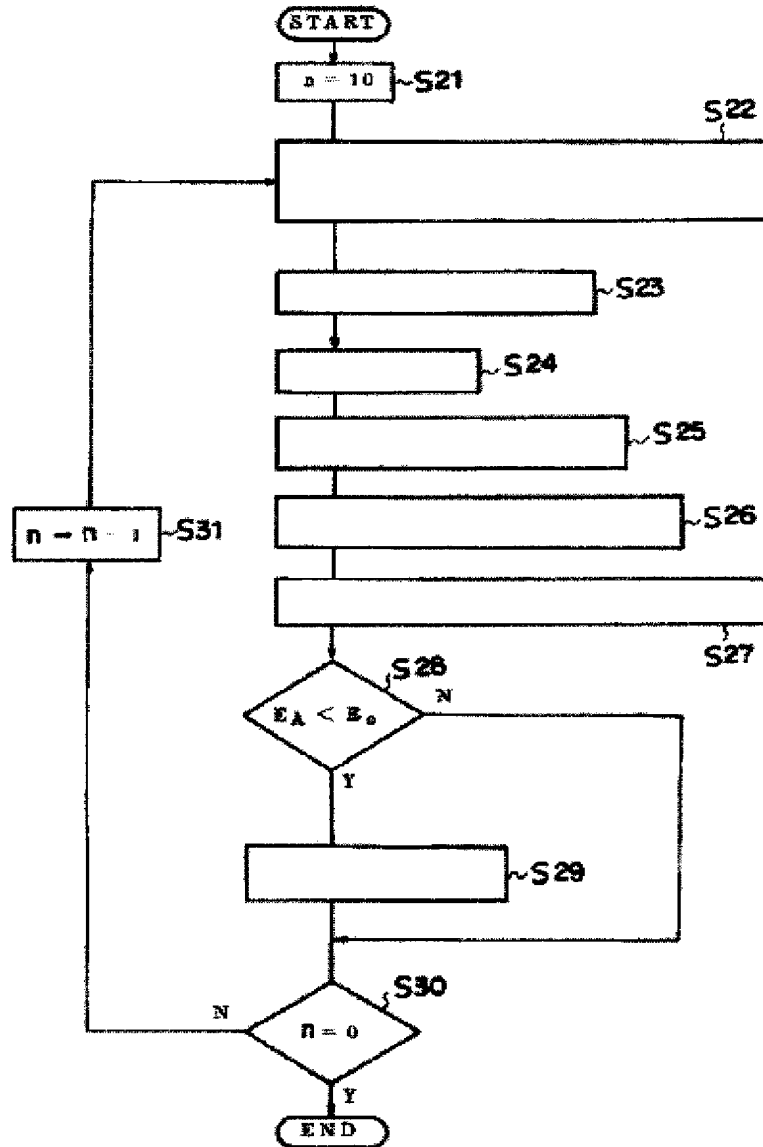


Figure 2.

- S22 nth bit of DAC is set at "1", (n-1)th bit ~ the least significant bit are set at "0"
- S23 Driving of LED
- S24 Measurement of light emission quantity
- S25 Virtual allocation of time correction bit
- S26 Computing of exposure energy after allocation
- S27 Computing of virtual average exposure energy
- S28 Comparison
- S29 Change in driving current

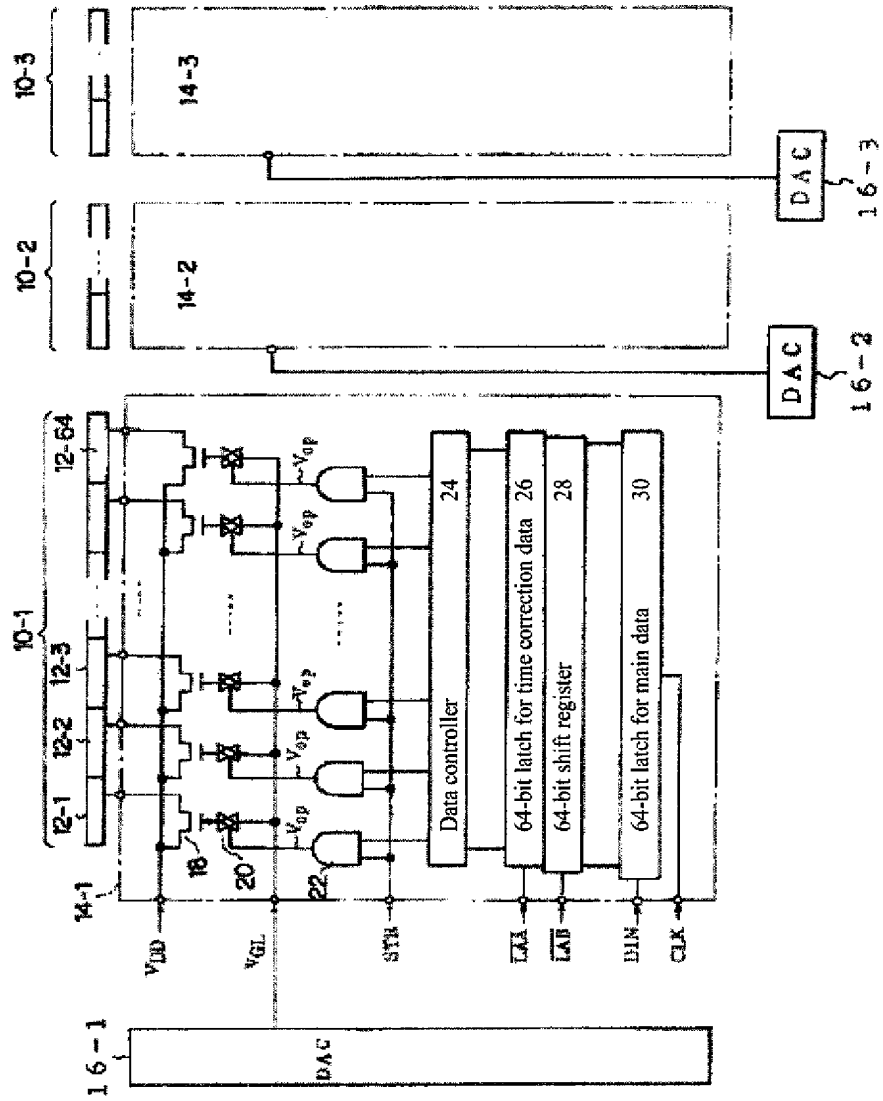


Figure 3.

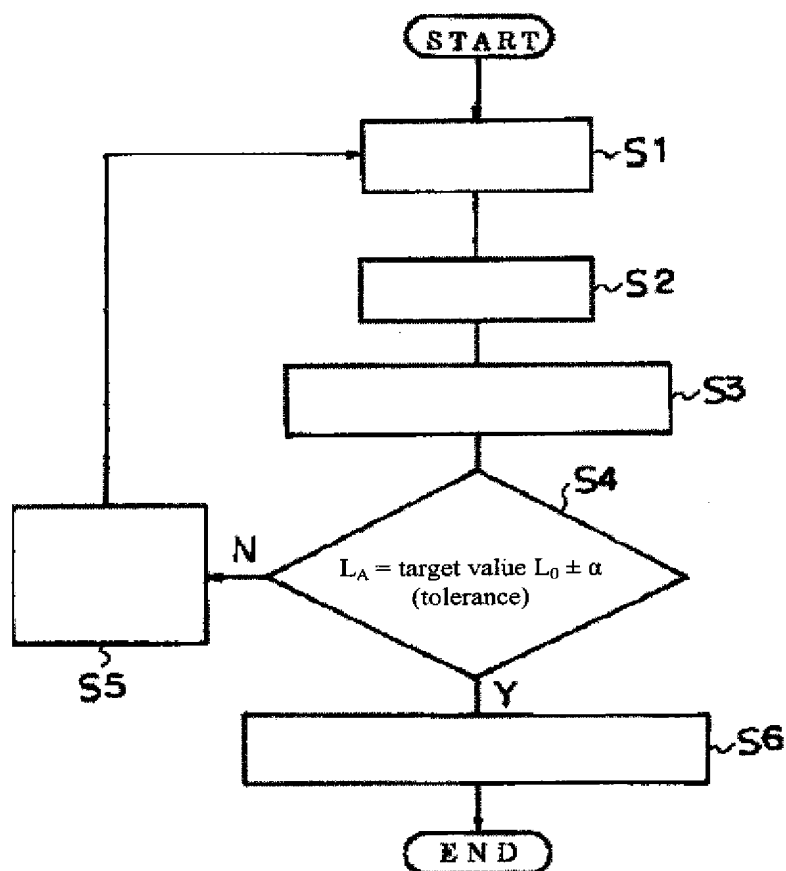


Figure 4.

- S1     Driving of LED
- S2     Measurement of light emission quantity
- S3     Computing of average light quantity  $L_A$
- S5     Change of driving current
- S6     Allocation of time correction bit

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